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Manufacturing Methods and Technology Report

Contract DAAB07-75C-0044

PHOTOLITHOGRAPHIC TECHNIQUES FOR SURFACE ACOUSTIC WAVE (SAW) DEVICES

L. Dyal
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GROUND SYSTEMS GROUP
HUGHES AIRCRAFT COMPANY
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August 1977

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SAW Packaging

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The object of the program is the establishment of a production capability for surface acoustic wave devices of varied design and material for the purpose of meeting estimated military needs for a period of two years after the completion of the contract and to establish a base and plans which may be used to meet expanded requirements. The primary requirement is the pilot line production of devices that are reliable, reproducible, and low cost.

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The first two phases of this program saw the design, fabrication and tooling of six device types, bandpass, pulse compression and tapped delay line SAW filters on both lithium niobate and ST-quartz substrates. The third phase involved fabrication of a larger quantity (50 ea.) of confirmatory devices which were sampled at a high rate and subjected to rigorous life and environmental testing. The fourth phase of the program is a pilot line production effort of 150 each of the devices scheduled to be delivered. This report describes the extent to which Phases III and IV have been met.

Phase III has been successfully completed with delivery and acceptance of the confirmatory samples. The device configuration is detailed as it exists for Phases III and IV along with assembly details, processing steps and results and conclusions from the Confirmatory Sample production run. Several problem areas are fully treated and include measures taken during Phase IV to minimize their impact.

Finally, the Pilot Line process is described step by step in its final configuration reflecting the experience gained during the first three phases and applied to result in increased yields and reliability and decreased production costs.

The remainder of the program will be devoted to completing the Pilot Line production run and doing a detailed cost analysis for future needs; to document the process in its entirety and to providing a Quality Control Manual.

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GLOSSARY

SAW - Surface Acoustic Wave

BP-Q - Bandpass Filter - ST Quartz Substrate

BP-LN - Bandpass Filter - Lithium Niobate Substrate

TDL-100 - Tapped Delay Line Filter - 100 MHz - ST Quartz Substrate

TDL-200 - Tapped Delay Line Filter - 200 MHz - ST Quartz Substrate

PC-Q - Pulse Compression Filter - ST Quartz Substrate

PC-LN - Pulse Compression Filter - Lithium Niobate Substrate

ST - Quartz orientation, ST cut (42° 45'), X propagating

YZ - Lithium Niobate orientation, Y cut Z propagating

SECTION 1.0
INTRODUCTION

Section 1.0

INTRODUCTION

This report presents the results of the Phase III completion as well as a preliminary Phase IV effort in satisfying the requirements of a Manufacturing Methods and Technology Program devoted to a representative range of surface acoustic wave (SAW) device designs.

1.1 PROGRAM OBJECTIVES

Production engineering measures are to be established by Hughes for Surface Acoustic Wave Devices. Under these measures Hughes is to establish or improve the producibility of specified devices by mass production techniques and with mass production facilities; establish a quality control system and take such actions as are necessary to reduce the time required for delivery of the contracted items that will be required in large quantity production for current planning and in the event of an emergency.

The objective of this program is to establish a production capability for the purpose of meeting estimated military needs for a period of two years after completion of the contract, and to establish a base and plans which may be used to meet expanded requirements.

Reports and other information procured under this requirement will be used for industrial mobilization and preparedness planning, to provide a basis for determining whether or not military requirements can be accomplished, to determine what additional planning measures are required and when necessary to assist in establishing additional sources.

1.2 PROGRAM PLAN

The program has been divided into four phases. The first addresses the design, fabrication and analytical testing of six prototype SAW devices that are representative of the current and potential application of the technology. While these device requirements do not represent the state-of-the-art in an R&D sense, they are of such complexity as to require a serious design effort in each case.

The second phase is to be utilized in the redesign of those devices that have failed the intended design specification. The net result of this

effort will be a functional electrical specification adherence based on a cost effective packaging commitment.

The third phase will test and confirm both the electrical and environmental commitment of the various devices to the specification. The final phase will test the reproducibility of those predetermined electrical and environmental requirements in a high volume production environment. A key result of this phase will be the establishment of meaningful manufacturing cost data on each device as well as a comparison of this data to the prior low volume efforts of the earlier phases.

1.3 PROGRAM ACCOMPLISHMENTS DURING THIS REPORTING PERIOD

Phase III confirmatory sample fabrication is complete. These devices (50 each of six different types) have been subjected at high sampling rates to rigorous testing according to MIL-STDs called out in SCS476. The devices successfully passed the imposed conditions and have been delivered. After go-ahead was received, pilot line production began on Phase IV devices. This production effort, though sporadic due to scheduling, has progressed smoothly due to the valuable experience gained in earlier phases of the program. Phase IV device fabrication is about 50% complete with device deliveries scheduled for the end of November 1977.

SECTION 2.0
MMT DEVICE CONFIGURATION

Section 2.0

MMT DEVICE CONFIGURATION

2.1 DEVICE DESCRIPTION

The six devices to be designed and manufactured during this program are of three different classes on two different substrate materials. The classes of devices are bandpass filters, pulse compression filters and tapped delay lines. The substrate materials are ST quartz and YZ lithium niobate ($LiNbO_3$). (The terms ST and YZ denote crystallographic orientation.) The individual SAW devices are further identified in tables 2.1-1, 1.1-2 and 2.1-3.

TABLE 2.1-1. MMT SAW DEVICE DESCRIPTION DATA

Designation	Device Class	Substrate Material	Center Freq.	Package Marking
BP-Q	Linear Phase Bandpass Filter	ST-Qtz.	100 MHz	B-Q-10-02
BP-LN	Linear Phase Bandpass Filter	$LiNbO_3$	150 MHz	B-L-15-30
PC-Q	Linear FM Pulse Compression Filter	ST-Qtz.	150 MHz	C-Q-15-50
PC-LN	Linear FM Pulse Compression Filter	$LiNbO_3$	150 MHz	C-L-15-50
TDL-100	Biphase Coded Tapped Delay Line Filter	ST-Qtz.	100 MHz	T-Q-10-10
TDL-200	Biphase Coded Tapped Delay Line Filter	ST-Qtz.	200 MHz	T-Q-20-10

TABLE 2.1-2. SUBSTRATE WAFER, MATERIAL AND SIZE

Material	Size	Orientation
ST Quartz	2" x 2" x .025"	$\pm 0^\circ 15'$
YZ $LiNbO_3$	2.1" x 1.75" x .020"	$\pm 0^\circ 15'$

TABLE 2.1-3. INDIVIDUAL DIE, MATERIAL, SIZE, ARRAY SIZE, DIE/WAFER

Designation	Substrate	Size	Array Size	Die/Wafer
BP-Q	ST Qtz.	.586" x .172"	3 x 11	33
BP-LN	$LiNbO_3$	.500" x .200"	4 x 8	32
PC-Q	Quartz	.800" x .200"	2 x 10	20
PC-LN	$LiNbO_3$	.650" x .115"	3 x 15	45
TDL-100	Quartz	2.0" x .220"	1 x 9	9
TDL-200	Quartz	2.0 x .155"	1 x 12	12

These devices have been constructed and tested both electrically and environmentally and conform to those specifications called out in SCS-476, Electronic Command's Technical Requirements, Appendix I.

2.2 ASSEMBLY DETAILS

Photolithographic mask arrays of the transducer geometries designed during the engineering phases were procured for batch processing the piezoelectric SAW substrates. Tables 2.1-2 and 2.1-3 show the dimensions of the substrates, die and array sizes.

Once the transducer arrays are photolithographically defined on these substrates, the substrates are diced. The individual die is mounted with attendant tuning circuitry into a hermetic type package, interconnected, tested and sealed for delivery. The individual MMT device layout is shown in Figure 2.2-1. The schematic representation is shown in Figure 2.2-2. The BP-Q, BP-LN and PC-Q all have series tuning inductors input and output. The PC-LN has no inductors. The TDL-100 and TDL-200 have inductors on the input only.

Included as an integral part of the transducer pattern is either a series or a shunt resistor. The resistors modify the real portion of the input impedance to meet the VSWR specification. Taking advantage of the electrical properties of the thin film metalization composing the transducer, the same film can be used for these resistors. All devices utilize a tapped resistor as shown in Figure 2.2-3A where if tap a or taps a and b are scribed successively, higher values of R can be obtained than if the taps are left unscribed. Figure 2.2-3B shows the shunt resistor

configuration used on the PC-LN.

The toroids (nominal value of .1 to 1 uh) are soldered to the package pins while interconnection between the SAW crystal and the pins is made with thermo-compression bonded 1 mil diameter gold wire. Both toroid and crystal are held in place inside the package with silicone adhesive. The package lid is sealed to the base with solder (Sn 60/P640) to provide hermeticity.

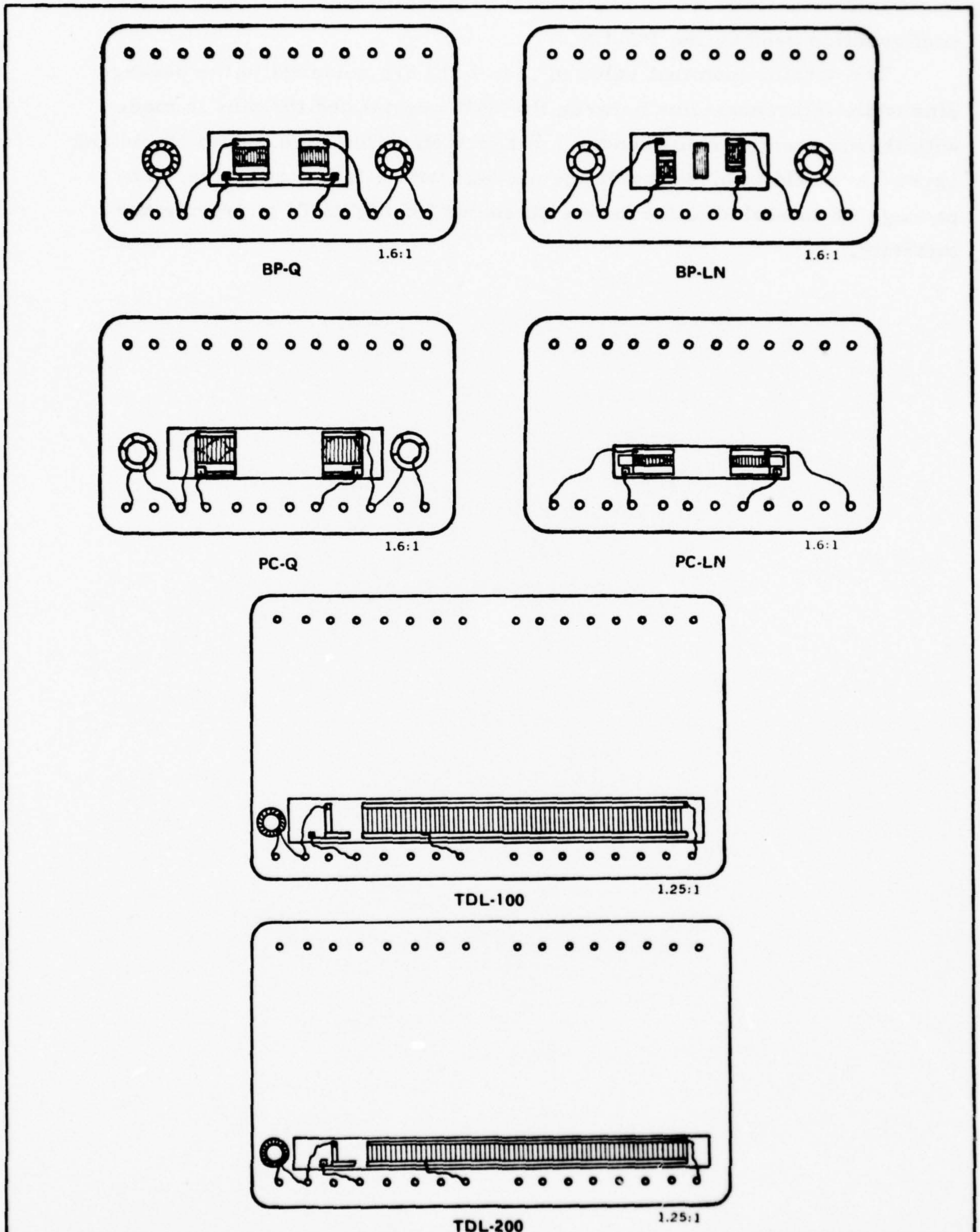

Figure 2.2-1. MMT SAW Device Configuration

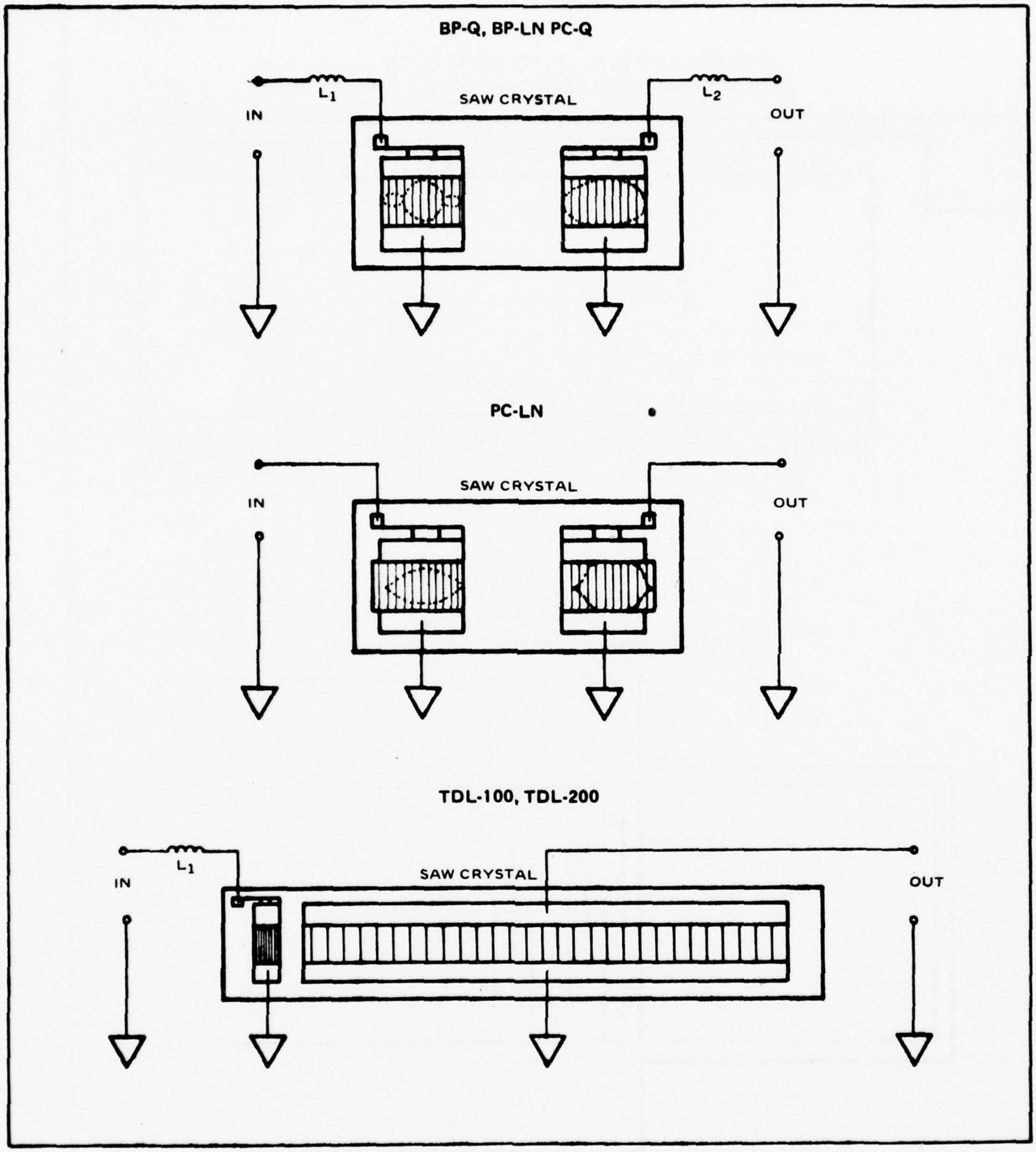

Figure 2.2-2. MMT SAW Device Schematic Representation

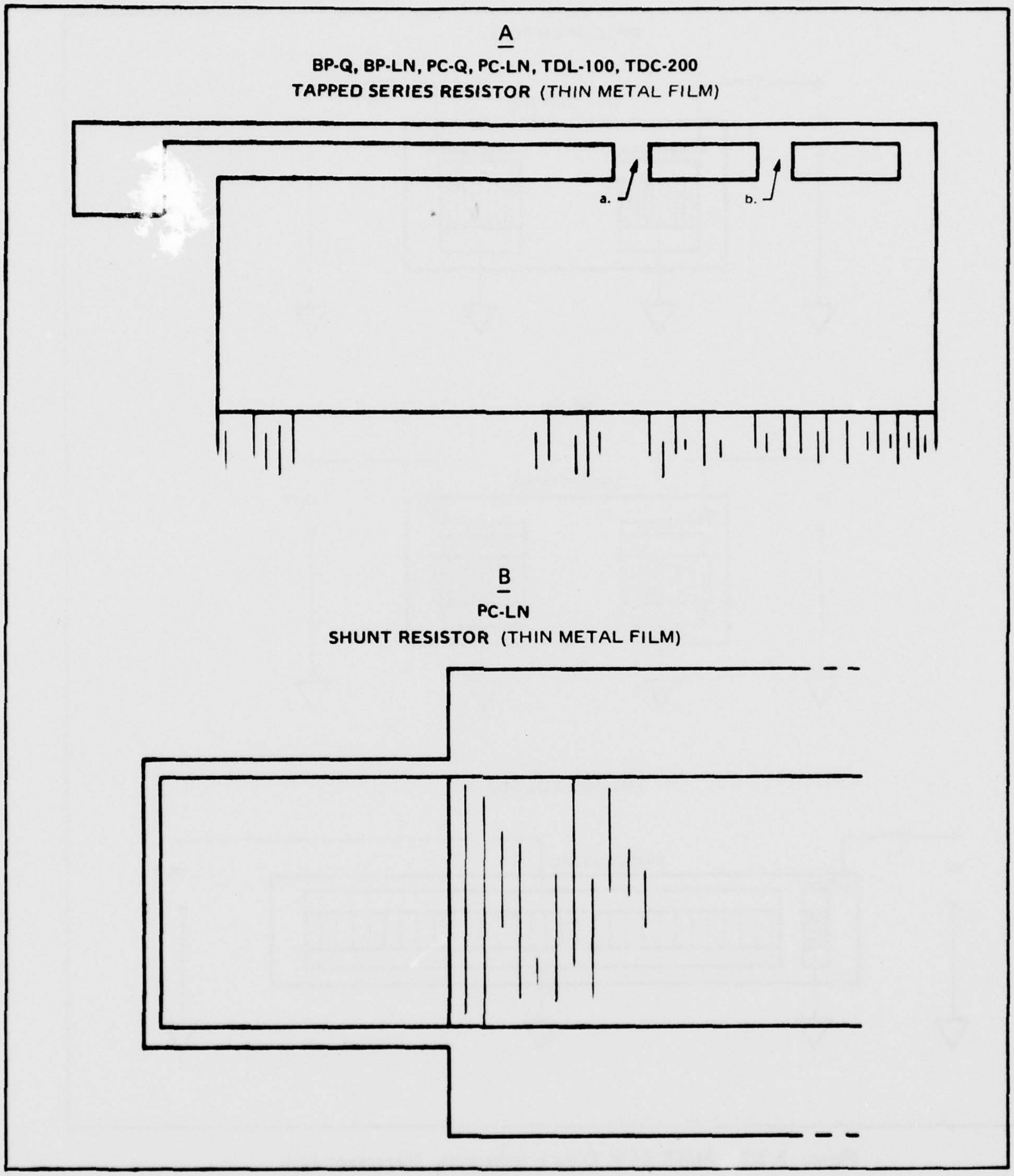

Figure 2.2-3. Resistor Detail

SECTION 3.0
CONFIRMATORY SAMPLE PRODUCTION RESULTS

Section 3.0

CONFIRMATORY SAMPLE PRODUCTION RESULTS

3.1 PROBLEM AREAS

Several problem areas connected with SAW device manufacture have been encountered thus far in the program. Investigations were conducted to correct each problem as it was identified. The following summarizes some of the results and observations.

3.1.1 Package Size

Package size has been a continuing problem throughout this program. A brief examination of the device layout as shown in Figure 2.2-1 reveals that much of the area within the package goes unused. Because the area being used tends to be long and narrow, it usually lies along one side of the package. The problem occurs when providing interconnects between the package pins and the bonding pads on the farthest side of the crystal. As a general rule these distances far exceed the 0.1 inch maximum length observed elsewhere within the semiconductor and hybrid industry. However, we may conclude as a result of the extensive testing during Phase III that the only impact of the excessive lead length is difficulty in processing. The excessive lengths may add to feedthru levels, but since feedthru is well within the specification limits (50 dB down), the actual contribution is unknown. This length was not identified as a failure mode during any of the life, environmental or electrical tests of Phase III.

An obvious alternative to using the present packages would be to use a narrower package. A cursory investigation at the beginning of the program indicated that none were available without special tooling. The tooling costs would be prohibitive for small quantity production runs (less than a thousand) and since the overall impact was minimal it was felt that use of available packages would serve the purposes of this program. However, packages of a more optimum size and pin configuration are recommended for use in SAW applications. An example of how such a package may be configured is offered in Figure 3.1.1-1. It shows packages of about the same length as those used in the MMT, but much narrower to allow the use of pins on both sides of the device.

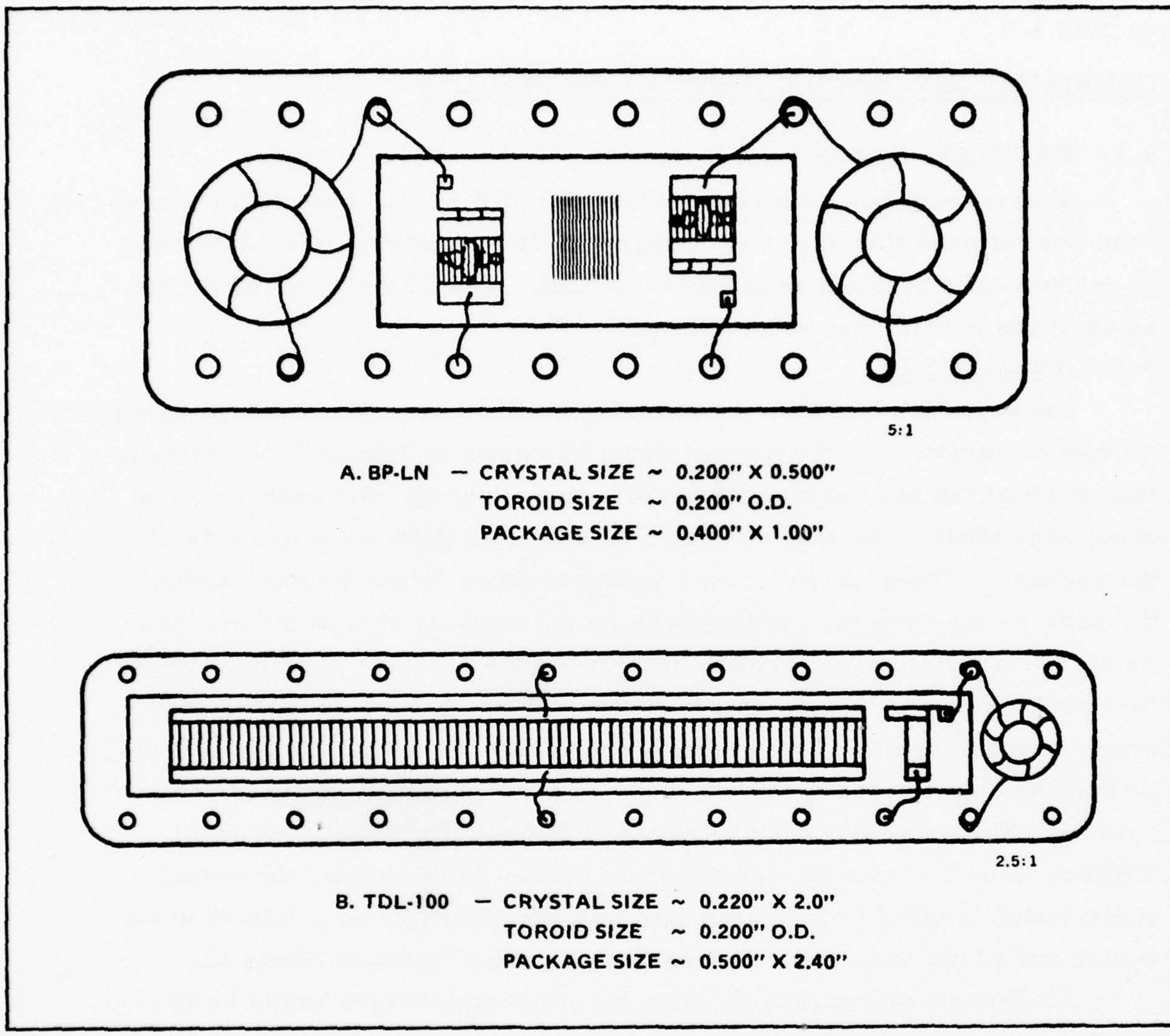

Figure 3.1.1-1. Proposed SAW Platform Packages of More Optimum Size and More Convenient Pin Configuration

3.1.2 Interconnection

Interconnection between the discrete toroid and the thin film SAW die posed a problem early in the program. Since these devices are electrically connected in a series there must be an interface somewhere between the #32 copper magnet wire of the toroid and the .001" gold wire connected to the SAW bonding pads. (Elaborate schemes of fabricating alumina chips with both solder and bonding pads and then attaching them as required showed promise of solving the problem, but at some expense and considerable labor.) The approach used was to take an existing unused package pin (of which there is usually an abundance in SAW applications) and use it as a standoff attaching both wires directly to it. The magnet wire is soldered and the gold wire is stitch bonded. The problem here is that if during the soldering operation the top of the pin gets covered with solder then this portion of the pin can not be thermocompression bonded. The solder cannot come in contact with the thermocompression bonded gold wire because of the well documented phenomenon of the gold wire alloying with the solder with resultant embrittlement and breakage.

With the use of a temperature controlled soldering iron and the proper tip, a technique was developed to solder the wire to the pin while only wetting the sides of the pin leaving the gold on the top of the pin for bonding. With relatively little training this operation has become one not only of high throughput, but of high yield as well.

3.1.3 Photolithography

Because of the small quantities involved in Phases I and II some of the transition between R&D and production held over into Phase III. Small quantities allow plenty of time for specialized attention to individual devices, and labor and yield are not so critical. Batch processing large quantities soon reveals weak points. Process flow must be smooth and uninterrupted. Device to device differences of any magnitude cannot be tolerated. The step by step procedures of fabricating these devices will be discussed in detail in a later section (Processing Equipment and Tooling). It is important to note here, however, the general approach or philosophy used in developing these processes was to keep the processes as simple as possible. In doing this, they are easier to understand and implement where unnecessary yield impacting steps are eliminated.

3.1.4 Electrical Testing

In manufacturing a surface acoustic wave, many different parameters must be taken into account. The specified electrical performance determines how exacting the processing and testing must be. The electrical specifications on the MMT devices, as called out in SCS476, were verified during the engineering phases of the program. Most of the possible electrical parameters associated with SAW devices were specified such as center frequency, bandwidth, delay time, time bandwidth product, insertion loss, sidelobe suppression, feedthru suppression, spurious signal level and VSWR. Limits were set to allow some variations from device to device and designs were finalized such that each device should operate around the center of these limits.

In actuality there are many things other than design items that can affect device performance. Theory sets the figures while reality tends to change them. The processing and assembly details that had to be closely controlled and sometimes corrected for were as follows:

3.1.4.1 Transducer metalization thickness. A computer controller was incorporated into the evaporator setup to insure consistency from run to run. Variations in metal thickness were found to affect several electrical parameters such as insertion loss, center frequency and time delay. Since no two runs will be exactly identical the amount of allowable variation had to be determined so that effective processes could be established.

3.1.4.2 Transducer metalization resistivity. This parameter primarily affects insertion loss since the resistive component of the transducer determines the percentage of applied electrical power that is available to be transformed into acoustic energy. Early in the program a few basic assumptions were made that at the time seemed safe. That is, the resistivity of thin film electron beam evaporated aluminum is essentially a function of its thickness. The evaporator system in the R&D facility that was used to fabricate the first two sets of engineering samples was fully characterized as to metal thickness versus resistivity and this data was incorporated into the device designs. When the confirmatory samples were fabricated on a newly established pilot line in another building the devices were found to perform substantially differently. This difference was traced to the fact that all e-beam aluminum is not the same and that the new evaporator was

producing lower resistivity material. This is shown graphically in Figure 3.2.4.2-1. The metal thickness and insertion loss relationship are shown in Figure 3.1.4.2-2. Fortunately, the changes in device operating characteristics were not severe enough to make them out of specification. However, they no longer operated at the center of the specification limits and as a result the yields on certain devices are lower than expected for Phases III and IV.

In conclusion, since both metal thickness and resistivity play an interacting part in device performance, they should be fully characterized as a function of production equipment prior to device design.

3.1.4.3 Toroid Orientation and Attachment. The MMT devices assembled with toroids require tuning prior to pre-seal testing. This amounts to squeezing or spreading the turns of the toroid to vary its inductance. Once tuned in this fashion the toroid is attached to the package base with silicone adhesive. It was noted during Phase III, especially with the BP-Q devices, that when the adhesive was dispensed through the center of the toroid so as to flow between the toroid and package base and filled the hole in the center, upon curing, the tuning would change due to changing dielectric properties of the adhesive and the parts would not meet the VSWR requirement. This situation was corrected by minimizing the quantity of adhesive used and not filling the hole in the center of the toroid. If a particular design is especially sensitive to slight drifts in tuning, then allowances should be made for these drifts during tuning.

A second problem arises as a result of tuning when, during subsequent testing, it is noted that feedthrough levels from one device to another are erratic, some within spec and some well outside. After considerable efforts to improve package grounding, which was the suspected cause, it was discovered that the primary contributor to the feedthrough was the orientation of the toroids (refer to Figure 3.1.4.3-1). Minimum inductance is achieved when the turns on the toroids are rather close together as shown. Now the electromagnetic coupling (feedthrough) between the two increases according to the angular position of an imaginary center of the wire mass. By rotating one or both of the toroids a few degrees the feedthrough can be drastically reduced, usually to within

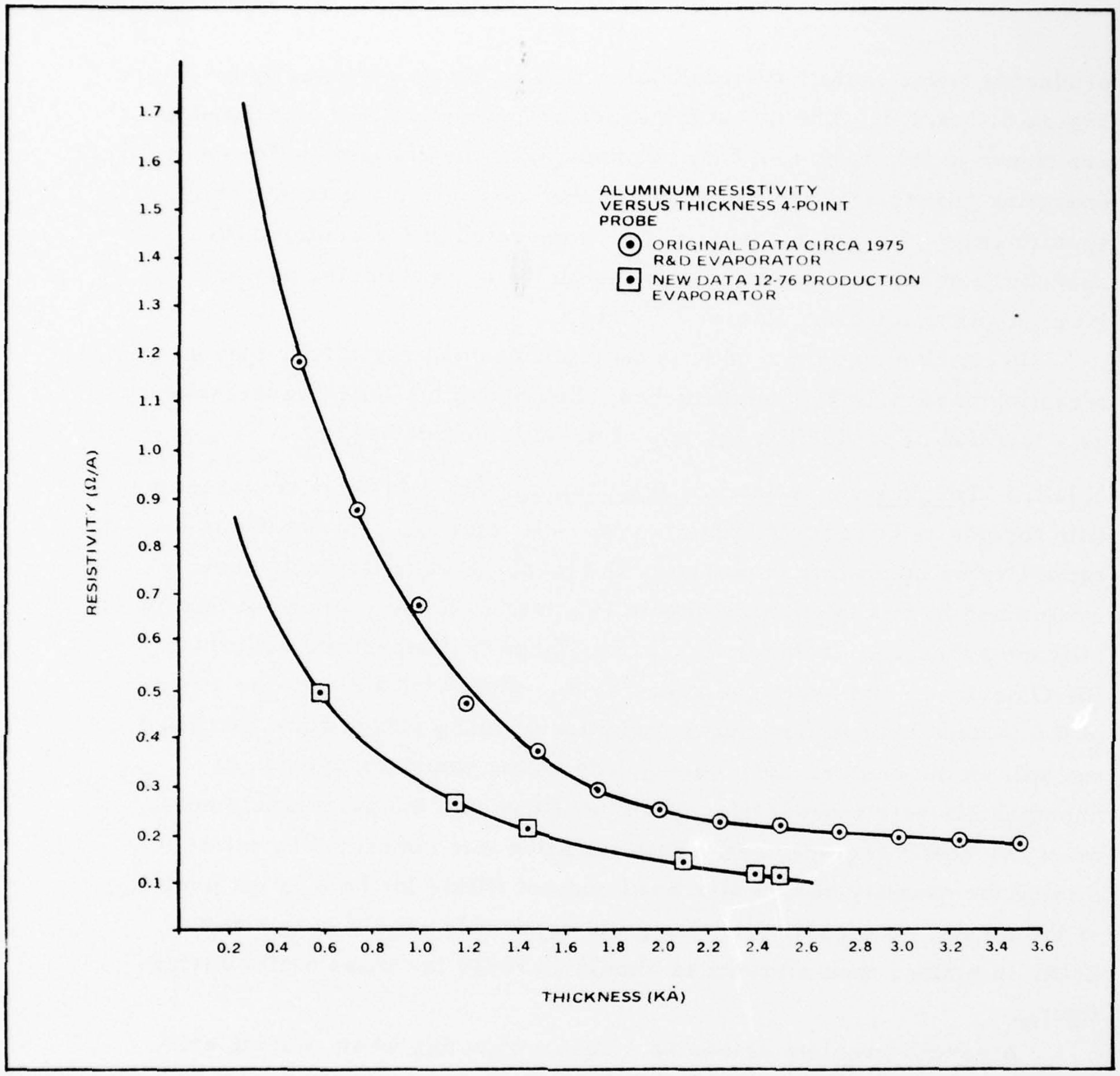

Figure 3.1.4.2-1. Resistivity of Electron Beam Evaporated Aluminum

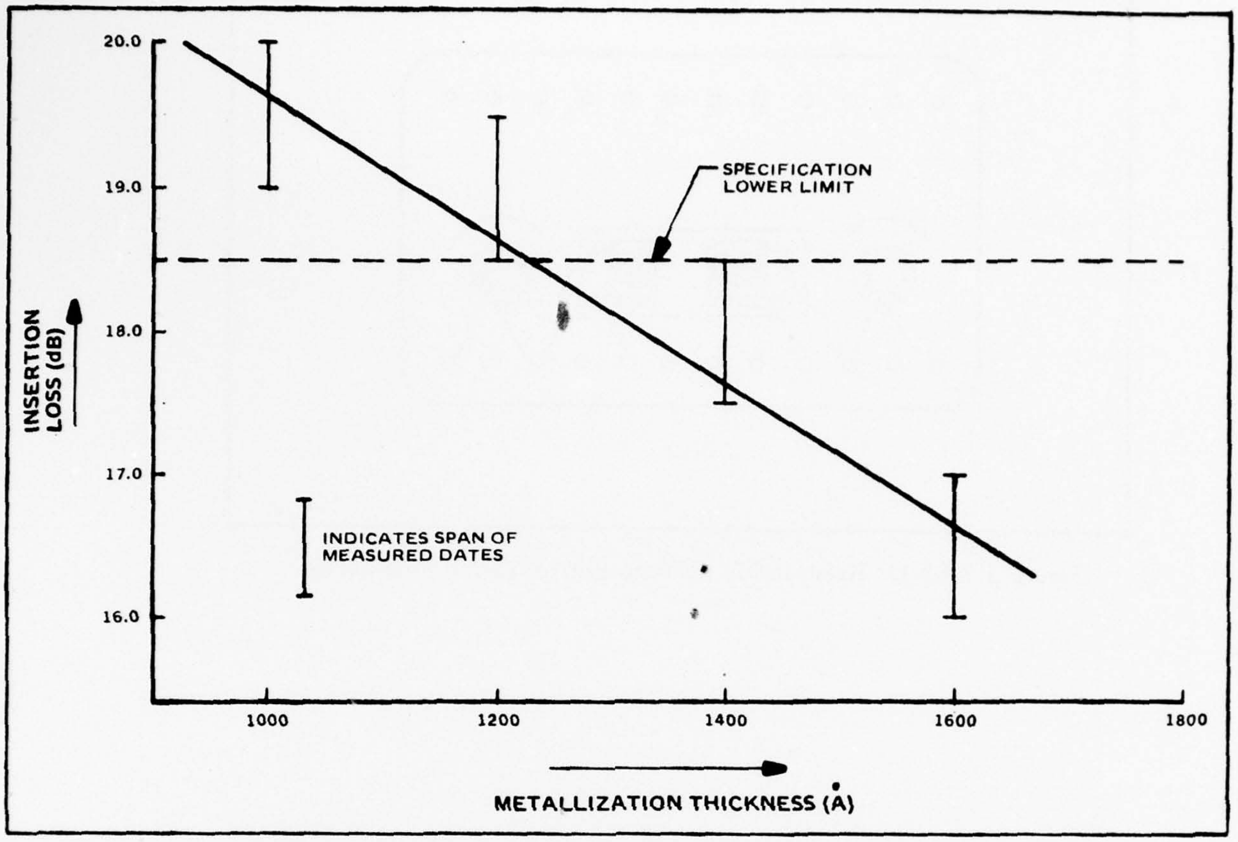

Figure 3.1.4.2-2. Insertion Loss as a Function of Metallization Thickness BP-LN

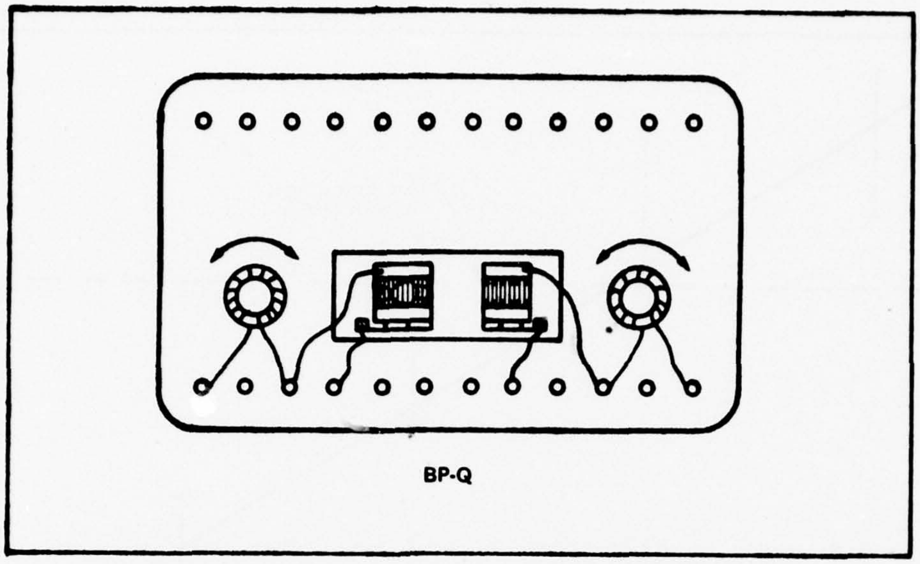

Figure 3.2.4.3-1. Relationship of Feedthru to Toroid Orientation

spec. It is important to recheck tuning for VSWR at this point to make sure the turns have not inadvertently been spaced resulting in a different inductance.

3.1.4.4 Grounding. If the packaged SAW device is operated in a fixture that does not provide adequate ground to the package itself then feed-through levels may be excessive. It has been observed that adequate device grounding cannot be achieved by grounding pins alone. The fixture that is to hold the device either during test or in an end product should include a ground plane beneath the package with a conductive medium such as silver loaded rubber or RFI gasketing connecting it to the package.

During the MMT program it was noted that after repeated use (many hundreds of insertion cycles) in the test fixture the conductive rubber (chomerics, Cho-Seal 12-12) would gradually become less conductive and more and more pressure was required to provide adequate grounding and meet the feedthrough requirement. Replacing the rubber solved the problem.

3.1.5 Substrate Dicing

Though substrate dicing in the semiconductor industry is well established, there remained much to be done to get SAW substrate dicing to the same point. Silicon wafers lend themselves well to the scribe and break technique; Quartz and lithium niobate, on the other hand, do not. Quartz does not necessarily break along a scribe line even if it is cut substantially through the wafer. Lithium niobate cleaves so easily in other directions that even if it too is cut nearly through, it wants to break in other directions. It was decided to dice both materials by cutting all the way through the wafer.

For dicing the wafers were mounted on glass plates which in turn were held by vacuum to the chuck of the dicing saw. The lithium niobate wafers offer little problem if they are mounted with double sided tape which after dicing can be peeled off rather easily. Quartz was a different matter. The tape method will not hold quartz securely, part way through dicing the wafer loosens, and violently ejects from the stage destroying most of the devices and at times damaging the blade. Optical

mounting pitch offered the required adhesion and, though it is time consuming and messy to implement, this is the method we have used. Because quartz is, by nature, a difficult material to cut, the dicing process is rather slow. It has been developed to the point of being high yield in spite of this. Earlier difficulties with the dicing saw not being able to cut quartz have been solved with a blade substitution and a saw modification as reported earlier.

SECTION 4.0
PROCESSES

Section 4.0

PROCESSES

Presented in this section are the processes, step by step, from incoming materials to sealed devices ready for delivery. Refer to Figure 4.0-1 where the process flow, including possible rework cycles is shown. Each step will be described in detail. There are two sections, one on die fabrication and one on device assembly.

4.1 DIE FABRICATION

4.1.1 Crystal Material Inspection

The crystals are observed with a microscope at 30 to 70X. The surface is scanned and imperfections, such as scratches, pits, residual patterns from previous processing, edge defects and other irregularities are noted. If a crystal is deemed suitable for processing, it is sent forward to the next operation.

Equipment and Material Required.

Equipment

Microscope, B&L Stereozoom, 30 to 70X or equivalent.

Material

Crystal substrate, of the material required, cut and polished.

4.1.2 Crystal Cleaning

The SAW substrates should be cleaned by using individual or a combination of the following procedures:

1. Detergent Cleaning. A detergent such as Turco Sudz is mixed with deionized water (1:20 by volume). Holding the substrate with tweezers, use a foam swab and scrub the substrate with detergent. Rinse with deionized water and blow dry with N_2.
2. Solvent Cleaning. Immerse substrate in a solvent such as acetone until it is visibly clear of foreign material. Scrub if necessary. Remove the substrate from the solvent and water rinse. Blow dry.
3. Acid Cleaning. Chromic acid is prepared (10g CrO, 10 ml H_2), 700 ml H_2SO_4) and the substrate is lowered into the acid with an acid resistant device for 5 to 20 minutes as necessary. Rinse in deionized water. Blow dry.

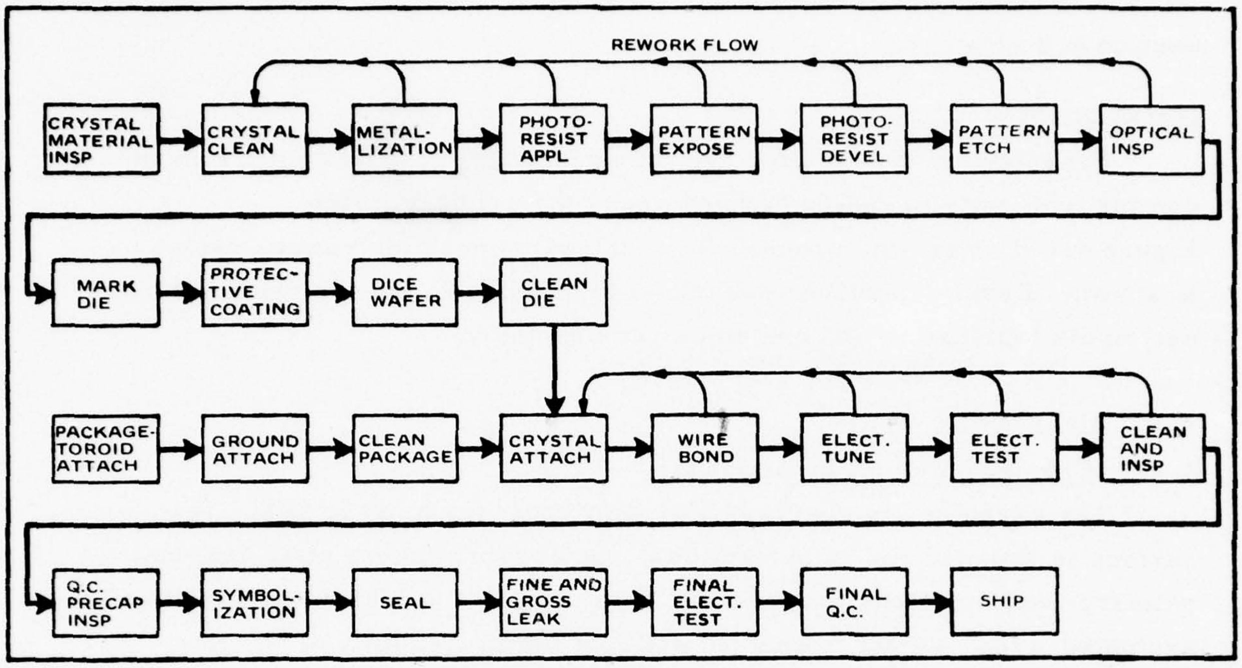

Figure 4.0-1. Typical SAW Device Process Flow

Equipment and Material Required.

Equipment

1. Sink with D. I. water and appropriate glassware.

Material

1. Chromium oxide, CrO_3
2. Sulfuric acid, H_2SO_4
3. Detergent
4. Acetone, reagent grade
5. D. I. water

4.1.3 Metalization

Cleaned substrates are metallized in an evacuated chamber with an e-beam heated source. The vacuum system is pumped to 5×10^{-6} torr prior to the actual evaporation. The evaporation parameters are programmed into the controller to minimize chance for operator error and to insure material uniformity from run to run.

Equipment and Material Required.

Equipment

1. Vacuum system (VE-400 or equivalent).
2. High voltage power supply (CVC Mod. LC031 or similar).
3. Electron beam equipment (Airco Temescal - STIH 270-2M, gun and CV-8, power supply or equivalent).
4. Evaporation controller (Inficon XMS-3 or equivalent).

Material

1. High purity aluminum (99.99% min.)

4.1.4 Photoresist Application

The SAW substrate is placed on the spinner and the surface flooded with an adequate amount of photoresist material. The vacuum is applied to the vacuum chuck and the spinner is activated. When the spinner stops, the vacuum is turned off and the wafer is removed and baked at $100^{\circ}C$ for 20 minutes.

Equipment and Material Required.

Equipment

1. Photoresist spinner (Solid State Equipment Model 103 or equivalent).

2. N_2 blow gun.

Materials

1. Photoresist (AZ1350B or equivalent as specified by Process Engineer)
2. Vacuum 20" or better.
3. N_2

4.1.5 Pattern Exposure

Pattern exposure requires use of procedures and equipment which will selectively expose a photoresist coated substrate so as to precisely duplicate the pattern on the photomask.

Depending upon the equipment available the exposure process may vary. Essentially, the exposure system is equipped with a high intensity mercury U.V. light source, a shutter and timer and some mechanism to hold the resist coated substrate in close contact with the photomask. This mechanism will have all adjustments and controls to accurately position the substrate to the pattern on the mask. With the alignment and contact requirement satisfied the exposure is made by opening the shutter for a fixed period of time. Exposure times for the MMT devices generally were 4 to 5 seconds depending upon the condition of the lamp (aging effects).

Equipment and Material Required.

Equipment

1. Alignment machine (Kasper 1800 or equivalent).
2. Photomask (as specified).
3. N_2 blow gun.

Material

1. $\sim$60 PSI regulated N_2 or air.
2. $\sim$15-20 PSI regulated N_2.
3. Vacuum 21" or better.

4.1.6 Photoresist Development

Exposed substrates are immersed in a developer solution (1:1, AZ developer:D. I. water) until visual indications show development is complete (usually $\sim$20 sec.). Variations in lamp intensity, exposure time,

developer concentration and temperature will cause the development time to vary somewhat. This does not compromise device quality. In fact, ability to vary development time is an aid in that it will compensate for other factors influencing the process. The operator can quickly gain the expertise necessary to properly develop photoresist. The substrates are then rinsed in D. I. water and blown dry.

Equipment and Material Required.

Equipment

1. Petri dishes or other suitable container for chemical solutions.
2. Photoresist spinner.
3. N_2 blow gun.
4. Sink.
5. Tweezers

Material

1. D. I. water
2. Developer solution (AZ Developer or as specified)

4.1.7 Etch

After a thin film coated substrate has had a photoresist pattern defined on it, the pattern must be etched into the thin film thus forming the actual circuit pattern in the thin film metal. This is done by immersing the substrate in an etch solution, removing when etch is complete, rinsing with D. I. water, and blow drying with N_2.

Equipment and Material Required.

Equipment

1. Petri dishes or other suitable containers for chemical solutions.
2. N_2 blow gun.
3. Sink
4. Tweezers

Material

1. D. I. water.
2. Etch solution
3. N_2

4.1.8 Optical Inspection

Once the transducer structures are defined in the thin film aluminum they must be optically inspected at 250X to identify. A map of good and bad dies on the substrate is prepared. Subsequent marking identifies those die to be culled out after dicing. If at this time a wafer yields too few good die (< 75%) then the metal is stripped off and the substrate reused.

A good SAW die should meet these general requirements:

1. There shall be no opens or shorts in the electrode fingers beyond that allowed for the particular device.
2. There must not be any contamination such as photoresist, finger prints, dirt, etc.
3. The pattern shall be parallel with the long axis of the crystal to the extent it can be determined with the unaided eye.
4. The pattern shall be centered between the ends of the crystal, unless otherwise indicated on the engineering drawing.

Equipment and Material Required

Equipment

1. Microscope (250X) with incident and transmitted light.
2. Tweezers.

Material

1. Finger cots.
2. Process follower sheet.

4.1.9 Mark Die

The SAW substrate being rough lapped on the back surface enables the individual die to be easily marked with a graphite pencil. The graphite imbeds in the roughed surface and is not removed during subsequent cleaning. This marking is visible after the die is mounted because the substrate material is transparent.

Equipment and Material Required.

Equipment

1. Graphite pencil.

4.1.10 Protective Coating

The completely processed and inspected wafer is prepared for dicing simply by providing a photoresist (AZ1350-T) protective coating over the substrate surface, covering and protecting the transducer structures. Their coating is applied as in step 4.1.1 Photoresist Application, using the same equipment and material.

4.1.11 Substrate Dicing

A dicing saw is used to cut processed wafers with multiple circuit patterns to yield individual die of a single circuit pattern. The quartz substrates are mounted to a glass plate for dicing by heating the glass plate, applying optical pitch to the top surface and placing the substrate (pattern side up) on top of the pitch. The excess pitch flows out from between the plate and the substrate and the assembly is left to cool. The glass plate is then held in the saw by vacuum and the substrate is diced. Once diced the die are removed from the glass plate by again applying heat. The $LiNbO_3$ wafers are held to the glass plate with double backed paper tape and when dicing is complete the die are easily peeled off and cleaned in acetone.

Equipment and Material Required.

Equipment

1. Dicing saw (Electroglas Model 106 or suitable substitute).
2. N_2 blow gun.
3. Sink.
4. Photoresist spinner.
5. Hotplate.
6. Petri dishes or other suitable containers for chemical solutions.
7. Tweezers.
8. Ultrasonic cleaner.

Material

1. D.I. water.
2. N_2
3. Facilities as required for equipment hookup and called out in equipment manual.

4. Optical mounting pitch.
5. Double backed paper tape.
6. Detergent (Turco Sudz or equivalent)
7. Acetone - reagent grade or better.
8. Lubricant (Kerfaid 101, 102, or equivalent
9. Photoresist AZ1350J or equivalent.

4.1.12 Clean Die

The die are cleaned in acetone to remove both the mounting pitch and the protective photoresist coating. Additional cleaning is performed as required as in step 4.1.2, using the same equipment and material.

4.2 SAW DEVICE ASSEMBLY

4.2.1 Toroid Attachment

When SAW devices are to be packaged with internal tuning, the tuning elements must be interconnected in a manner that is compatible with subsequent thermo-compression bonding.

The toroid leads (#32 AWG) are wrapped around and soldered to the appropriate platform package pins in such a way that a good solder joint is formed between the wire and the pin without covering the top of the pin with solder. The key function here is careful application of the right amount of heat to the wire so the solder does not wick up the pin.

Equipment and Material Required.

Equipment

1. Low power microscope 30 to 70X
2. Temperature controlled soldering iron.
3. Tweezers.
4. Wire cutters.

Materials

1. Platform package (as specified)
2. Toroids (as specified)
3. Rosin core solder (SN 60/Pb 40, 63/37 or as specified).

4.2.2 Ground Attachment

Electrical components may be soldered by hand onto the package base for adequate grounding. Precautions should be taken to ensure proper solder flow between the component or wire and the package base to prevent cold solder joints.

Equipment and Material Required.

Equipment

1. Microscope 7x to 30x magnification
2. Microscope light
3. Soldering iron
4. Tweezers

Material

1. Solder - QQ-S-571, Type W-RMA-P2 or P3, composition SN 60, SN 63 or SN 96.
2. Solder Flux Allros 100, Type R or Kester 197, Type RMA per MIL-F-14256 or equivalent.

NOTE: The color of the solder can range from a dull gray to a bright shiny silver color. A grainy appearance indicates gold in the solder and is not cause for rejection.

There shall be no cracks or separations visible between the element solder joints and the substrate.

Solder connections must be free of flux residue.

Solder shall not extend into the passive (insulating) substrate areas such that the spacing between adjacent conductors is reduced by more than 75%. It shall not extend above the element to the extent that it interferes with package sealing.

4.2.3 Package Cleaning

After the discrete components are attached to the package header and prior to attaching the SAW crystal, the package should be cleaned to remove flux residues and other contamination from previous processing. Packages are immersed in isopropyl alcohol and ultrasonically agitated for five minutes, removed to a clean alcohol rinse and blown dry.

Equipment and Material Required.

Equipment

1. Necessary beakers and containers.
2. Ultrasonic cleaner
3. Tweezers
4. N_2 blow gun

Material

1. Isopropyl alcohol
2. N_2

4.2.4 Crystal Attachment

The SAW die is to be mounted to a package or a substrate in such a way as to provide minimal mechanical stress to the crystal and to absorb excess acoustic energy at the ends of the crystal.

Silicone rubber adhesive (Dow Corning 3140) is used for SAW die attach because it isolates the SAW crystal from strain induced by thermal expansion of the package during temperature excursions. The same material also lends itself well as an acoustic absorber and is used to coat the ends of the crystal to absorb this excess acoustic energy.

A dispenser for this material has been designed and built such that an exact amount of adhesive used can reproducibly be very accurately dispensed.

Equipment and Material Required.

Equipment

1. Dispenser (Hughes RTV dispenser or equivalent).
2. Tweezers
3. Syringe

Material

1. Dow Corning 3140 or equivalent.

4.2.5 Wire Bond

The SAW crystal is electrically connected to the package pins via thermo-compression bonded .001" dia. gold wire. To avoid the necessity of using stage heat and subjecting the package to extreme temperatures and thermal shock a pulsed tip bonder is used. A ball bond is formed

on each of the four (4) transducer bonding pads and stitched over to the appropriate package pin as shown in Figure 2.2-1.

Equipment and Material Required.

Equipment

1. Bonder - Hughes HPB-360 or equivalent.
2. Tweezers

Material

1. Gold wire, .001" dia., 8-12% elongation factor.

4.2.6 Electrical Tuning

After a SAW device containing tunable elements has been assembled, it must go through a tuning procedure to adjust the electrical value of these elements. This is a dynamic adjustment performed under operating conditions to insure optimum device performance.

The toroid turns are moved either closer together or farther apart to achieve the correct value of inductance. Once the inductance is set the toroid body is attached to the package base with silicone adhesive. A moderate amount of adhesive is applied between the outside edge of the toroid and the package base to minimize its effect on the tuning.

If there is a resistor element as part of the thin film circuit and it has taps for adjustment, then these taps may be scribed open to increase the resistor value. This is a one way operation and should be done only as required. Lower values of resistance cannot be restored in present designs.

Equipment and Materials Required.

Equipment

1. Low power microscope 30 to 70X
2. Tweezers
3. Hand scribe
4. Electrical test equipment (as specified in Confirmatory Sample Test Report)

Material

1. Silicone adhesive (Dow Corning 3140 or equivalent)

4.2.7 Electrical Test

The assembled SAW device is tested prior to sealing to insure that it meets all electrical parameters. The test is described in detail in the Confirmatory Sample Test Report.

4.2.8 Q.C. Precap Inspection

A fully assembled, properly functioning SAW device is subjected to Q.C. visual inspection to check for conformity to design and to MIL-STD-883. Any nonconformity is corrected prior to package sealing.

Generally the following criteria are applied, however, more detail is included in MIL-STD-883.

The package must be free of all loose foreign conductive material prior to sealing.

Wire bonds shall not have tails exceeding 3 mils nor shall they extend more than 50 percent into any insulating area.

Strapping or welds must be at least 50% within the pad to which they are attached.

The package shall contain no broken, kinked or twisted leads. Packed leads shall have a minimum of 90 percent gold plating coverage. Cutoffs on the lead ends shall not be included.

Conductor and resistor lines shall not be reduced by more than 50 percent of the design width by scratches, peeling voids, cracks, etc., which reveal bare substrate material.

The substrate shall be free of cracks.

Substrates shall be free of contamination which is detrimental to the circuit operation. Loose particles capable of being removed shall be blown off the substrate with a jet of nitrogen.

Residual unetched material on substrates shall not be cause for rejection provided that on conductors, there is a minimum of 0.025 mm (0.001") isolation between active elements.

Residual unetched material on resistors shall not be cause for rejection provided that the resistor remains within the untrimmed design limits.

If foreign particles are loose they shall be removed by a gentle jet of nitrogen only.

Residual photoresist on the surface of the die is not acceptable.

Wires from dice to substrate shall not contact edge of dice.

Nicks in wires shall not reduce cross-section of wire to less than 75 percent of its original value.

Burn marks on substrate or header are acceptable provided that all loose carbonized material around the burn area is removed and the burn does not cause resistors, conductors or devices to change beyond their normal specification limits.

There shall be no loose, or unattached tails left on the substrate after welding or wire bonding.

Equipment Required.

Equipment

1. Microscope and light, 30 to 70X magnification.

4.2.9 Symbolization (Marking of Microelectronic Devices)

The hybrid circuits should be marked by an offset printer in such a fashion as to be clearly legible and permanent.

Equipment and Material Required.

Equipment

1. Printer, Markem Model 1300, or equivalent.
2. Aluminum tray.
3. Brush, acid.
4. Tweezers.
5. Oven, Precision Scientific, capable of 150°C, max., or equivalent.
6. Sealed SAW devices.

Material

1. Markem specialty ink, black, 7224, FRS, per 760707.
2. Markem cleaner, 320.

4.2.10 Solder Seal

The packages are sealed in an inert nitrogen atmosphere with a maximum moisture of 20 ppm. The lids are soldered onto the headers by hand. They must be free from cracks, pinholes, excessive bulges or cavities and must have a continuous fillet of solder. They must pass fine and gross leak tests.

Equipment and Material Required

Equipment

1. Dry box, nitrogen atmosphere equipped with vacuum.
2. Soldering iron, American Beauty, or equivalent.
3. Solding iron, Ungar, 50 watt tip, or equivalent.
4. Holding fixture (tinning)
5. Holding fixture (sealing).
6. Tweezers.
7. Aluminum trays.

Material

1. Solder - QQ-S-571, Composition-Sn 63, or Composition-Sn 96. Solid core solder shall be used.
2. SAW circuits that have passed pre-cap inspection.
3. Package lid.

4.2.11 Fine and Gross Leak Tests

The sealed packages are placed in a vessel pressurized with helium for five hours. The packages are then placed in a leak detector calibrated to detect helium. Packages exhibiting leak rates exceeding 5×10^{-8} cc/sec are to be sent back for resealing.

Equipment and Material Required.

Equipment

1. Tank capable of internal pressure to 3 atmospheres.
2. Veeco Leak Detector, MS-9AB, or equivalent.

Material

1. Helium gas, Airco, MRO No. 10-0300, or equivalent.
2. Nitrogen, liquid, Airco, MRO No. 10-0351, or equivalent.
3. Applicable sealed SAW devices.

The gross leak test will reveal any large leaks in the package. The package is placed in a hot fluorocarbon (125°C) and observed for 90 seconds minimum for air bubbles from the leak.

Equipment and Materials Required.

Equipment

1. Hot plate capable of 250°C, minimum.
2. Thermometer capable of 130°C.
3. Ring lamp with 10X magnifier.

Material

1. Fluorochemical - FC-43, FC-40, FC-48, FC-77, FC-78, 3M Company, or equivalent.
2. Glassware as required.
3. Applicable sealed SAW devices.
4. Magnetic package holding fixtures.
5. Dry nitrogen (N_2)

4.2.12 Final Electrical Test

The SAW devices are again electrically tested to make sure no damage was incurred during the sealing cycle. This test is fully described in the Confirmatory Sample Test Report.

4.2.13 Final QC Inspection

Finished SAW devices are subjected to final visual inspection for proper marking, workmanship and possible physical damage.

SECTION 5.0
CONCLUSIONS

Section 5.0

CONCLUSIONS

During this reporting period experience gained and added to that of the Engineering and Confirmatory phases has resulted in a smooth running and productive initial pilot line effort. Although continuously shifting of priorities and schedules have been necessitated, significant advances are being made towards realizing the purpose of the program. Problems associated with SAW device manufacture have been encountered and dealt with effectively. The required device designs are capable of being produced and tested according to MIL STD imposed conditions and at a reasonable cost. In the area of future cost reduction consideration should be given to packaging and tuning requirements.

5.1 PROGRAM FOR NEXT INTERVAL

The remainder of the SAW MMT Program will be devoted to completing the Pilot Line production run, process documentation, and writing the Final Report. The Pilot Line production run will further establish processing and cost data as well as verify yields and throughput capability.

REFERENCES

	Source
SCS476	USAECOM
ECIPPR No. 15	USAECOM
MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-883	Test Methods and Procedures for Microelectronics
Quarterly Reports 1 through 5 - Contract No. DAAB07-75C-0044	Hughes Aircraft Company
1st & 2nd Eng. and Confirmatory Sample Test Reports - Contract No. DAAB07-75C-0044	Hughes Aircraft Company

APPENDIX I

Appendix I

MANPOWER SUMMARY

1 November 1976 to 31 August 1977

Function	Name	Title	Man Hours
PMO Support	L. Dyal	Member Technical Staff	135
Quality Control	H. Cheseboro	Technician	22
Fabrication	L. Dyal	Member Technical Staff	960
	D. Coffey	Technician	140
	G. Blurton	Technician	210
	I. Rios	Technician	65
	C. Kasal	Technician	12
	R. Small	Technician	38
	C. Glass	Technician	16
	J. Knoop	Technician	12
	M. Parker	Technician	16
	O. Astgen	Technician	12
Test	R. Kolb	Member Technical Staff	220
	C. Kasal	Technician	25
Quality Testing	B. Nishitsuji	Technician	68
	D. Lanford	Technician	30
	D. Brown	Technician	22
	T. Bates	Technician	8
	G. Allen	Member Technical Staff	17
	E. Alldredge	Technician	16
	G. Orris	Technician	13
	J. Tait	Technician	20
	J. Geil	Technician	8
	A. Hallowach	Technician	10
	L. Chapman	Technician	8
	B. Thomas	Technician	9

PUBLICATIONS, REPORTS AND CONFERENCES

A technical status report, "Progress Report on Surface Acoustic Wave Device MMT-II," was delivered by A. R. Janus at the Annual Frequency Control Symposium at Atlantic City on June 1 and 2, 1977, and by L. Dyal at the AVS-ISHM Thick and Thin Film Application Conference in Los Angeles on May 31 and June 1, 1977.